Evaluation of the relationship among time of ocean entry, physical and biological characteristics of the estuary and plume environment, and adult return rates, 2002

Fish Ecology Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

by
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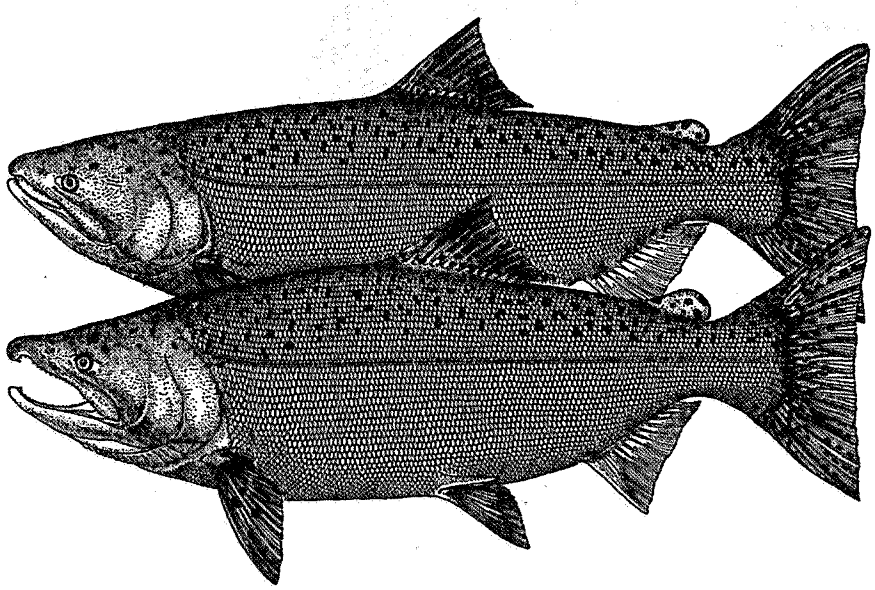

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Report of research by

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EXECUTIVE SUMMARY

This study examines the relationship among time of juvenile salmon ocean entry, physical and biological characteristics of the estuary and nearshore ocean plume environment, and smolt-to-adult return rates (SARs) for spring chinook salmon reared by the Clatsop Economic Development Committee Fisheries Project in the lower Columbia River.

During 2002, six groups of yearling spring chinook salmon were transferred from Willamette Hatchery to net pens in Blind Slough in the Columbia River estuary, reared for 10 days, and released at 10-day intervals from 10 April through 30 May. Size and smolt development (gill Na^+-K^+ ATPase activity) at release were similar among groups. Coded-wire tags will be recovered from adults beginning in 2004 from the Blind Slough terminal gill net fishery.

Smolt-to-adult-return rates for serially released groups of coded-wire-tagged spring chinook salmon will be integrated with information collected from ongoing studies funded by Bonneville Power Administration (BPA) and others characterizing the physical and biological conditions of the estuary and plume environment. By enhancing our understanding of the linkages between ocean entry and the physical and biological estuarine and ocean conditions that the smolts encounter, we can optimize SARs by manipulating transportation tactics and hatchery release dates.

CONTENTS

INTRODUCTION

The effects of short- and long-term fluctuations in oceanographic and climatic conditions on survival of salmon have received increased attention in the Pacific Northwest as salmon runs have declined (NRC 1996, Emmett and Schiewe 1997, Williams et al. 2000). Growth and survival of salmonids in their first days and months at sea appear to be critical in determining overall salmonid year-class strength. This is based on the relationship between returns of jack salmon after only a few months at sea and numbers of adults returning from the same brood class in later years, and ocean purse seine catches of salmonids in June that correlate well with jack and adult returns (Percy 1992).

The Columbia River estuary has been significantly altered by human development (Sherwood et al. 1990, Weitkamp 1994). Seasonal flow patterns have been altered by dam construction, and salmonid habitat has changed as a result of dredging, diking, and urbanization. Exotic species introductions and large-scale salmonid hatchery programs have radically changed the species mix in the Columbia River estuary. Furthermore, ocean conditions appear to vary significantly both spatially and temporally at a variety of scales (Francis et al. 1998, Welch et al. 2000). The relative importance of these factors to juvenile salmon survival is not well understood.

Increasing our understanding of variations in estuarine and nearshore ocean environments, and the role these variations play in salmonid survival, could provide management options to increase adult returns. Smolt-to-adult-return (SAR) rates for PIT-tagged smolts that are collected and transported vary greatly within years (Marsh et al. 2000). Past studies have documented little mortality during actual transport, and recent studies using juvenile radio tags have indicated rapid migration and high survival to the Columbia River estuary after release (Schreck and Stahl 1998). Recent studies of smolt survival during downstream migration through Snake and Columbia River reservoirs and dams have also shown little variation in survival within or between years (Muir et al. 2001,Williams et al. 2001). Therefore, changes in direct survival during migration through fresh water do not appear to explain observed changes in SARs for groups of fish within or between years.

Characterization of the conditions that smolts encounter in the estuary and nearshore ocean and of SARs on a temporal basis should allow us to identify which estuarine or ocean biological/physical conditions are correlated with high or low levels of salmon ocean survival. Managers can potentially use this information to determine optimal times for hatchery releases, or whether to transport smolts from collector dams or allow them to migrate naturally to synchronize their arrival to the estuary and nearshore ocean during optimal conditions.

Conditions that might vary in the estuary and nearshore ocean and affect salmonid survival include the abundance of predators (birds, fish, and marine mammals), alternative prey for those predators (northern anchovy, Pacific herring, Pacific sardine, and euphausiids), and the salmonids'own prey (optimally allowing smolts to grow rapidly thus reducing their vulnerability to predators). Dramatic changes in predator and baitfish populations off the coast of Oregon and Washington have been documented in recent years (Emmett and Brodeur 2000).

This National Marine Fisheries Service (NMFS) study examines the relationships among time of salmonid ocean entry, physical and biological characteristics of the Columbia River estuary and nearshore plume environment, and SARs for yearling chinook salmon. The objectives are to:

1) estimate SARs of serially released yearling chinook salmon through the spring migration period,
2) characterize variations in the physical and biological conditions in the Columbia River estuary and nearshore ocean environment during periods of release,
3) determine the level of physiological development and disease status of smolts at release,
4) correlate SARs with environmental conditions, and
5) identify potential indicators (biotic, abiotic, or a combination of both) of salmonid marine survival that could be used to improve management actions.

In addition, the results from this study will provide valuable information to the Clatsop Economic Development Committee Fisheries Project (CEDC) to assess potential release strategies to maximize SARs.

METHODS

In the fall of 2001, about 150,000 spring chinook salmon, a mix of Clackamas and North Santiam stocks, were obtained from Oregon Department of Fish and Wildlife (ODFW), mixed, then divided into six groups of about 25,000 fish each, and reared at Willamette Hatchery in separate raceways. Each of the six groups were coded-wire tagged (CWT) with each group receiving a different tag code (Table 1). A sample of about 500 fish from each release group were examined at the hatchery in early April to determine CWT retention and adipose fin removal rates. About 3,000 fish in each group were also tagged with passive integrated transponder (PIT) tags (Prentice et al. 1990) to account for avian predation by Caspian terns (*Sterna caspia*) and double-crested cormorants (*Phalacrocorax auritas*) nesting on East Sand Island (River Kilometer, RKm 8) in the Columbia River estuary (Ryan et al. 2001; Table 2). Raceways were periodically swept with a magnet to collect shed PIT tags, and all mortalities were scanned for PIT tags to determine final PIT-tag release numbers. Feeding rate was adjusted so that each group would be similar in size at release, with a target size of 140-150 mm.

Beginning in April 2002, individual groups of fish were transported by truck (5,000 gal) to net pens located in Blind Slough in the lower Columbia River (Fig. 1) every 10 days from early April through the end of May. The net pens, owned and operated by the CEDC, are 6.1-m wide x 6.1-m long x 2.4-m deep. Using the CEDC facilities reduces the numbers of hatchery fish needed to evaluate adult returns because they have high return rates and the terminal lower Columbia River fishery is heavily monitored to recover CWTs. Furthermore, the mortality associated with migration through fresh water is minimized because the CEDC facilities are located in the Columbia River estuary.

Smolts were sampled prior to release to determine their level of physiological development and health using standard assays. Gill Na^+-K^+ ATPase activity was measured on the date of arrival in Blind Slough and 10 days later at release. Gill filaments were trimmed from the gill arch from 15 fish on each sample date, placed into microcentrifuge tubes containing sucrose, ethylenediamine, and imidazole (SEI) and immediately frozen on dry ice. Gill Na^+-K^+ activity was determined according to the method of McCormick (1993). Fish health was inspected monthly and just prior to release for each raceway by an Oregon State University pathologist.

Table 1. Release dates, coded-wire tag codes, percent tag loss, tag loss days (between tagging and examination), and sample sizes for Willamette Hatchery yearling spring chinook salmon released into Blind Slough in 2002.

Release date	Tag code	Percent tag loss	Tag loss days	Sample size
10 April	090120	14.3	194	526
19 April	090119	15.7	204	547
30 April	090121	16.9	202	539
10 May	090122	13.4	201	521
20 May	090123	15.2	195	513
30 May	090124	14.0	194	523

Table 2. Yearling spring chinook salmon release dates, number of PIT tags shed in raceways, PIT-tag mortalities, and total numbers with PIT tags released into Blind Slough in 2002.

Release date	Number PIT-tagged	Number of shed tags and mortalities	Number with PIT tags released
10 April	2,963	37	2,926
19 April	2,936	65	2,871
30 April	2,912	88	2,824
10 May	2,932	68	2,864
20 May	2.925	76	2,849
30 May	2,901	100	2,801

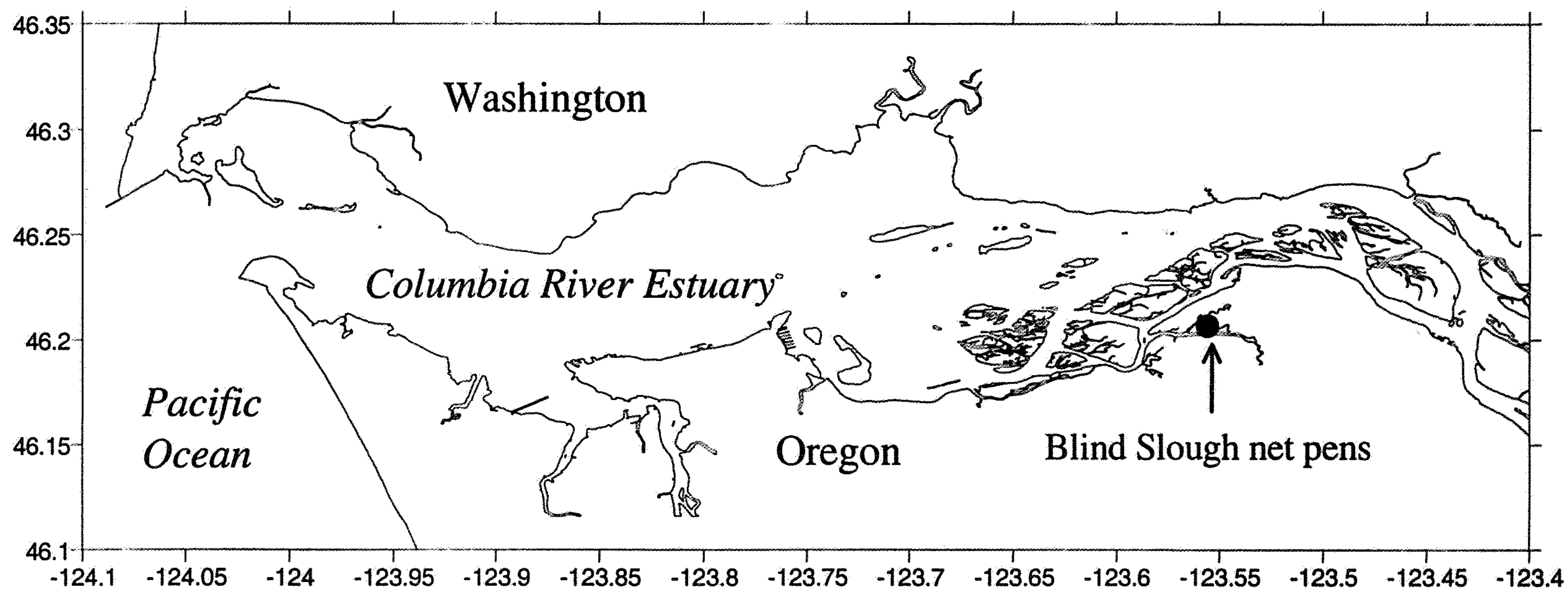

Figure 1. Study area showing location of Blind Slough net pens in the upper Columbia River estuary where Willamette Hatchery yearling spring chinook salmon were acclimated and released during 2002.

While in the net pens, fish were fed Oregon Moist Pellet, 5 days/week to satiation. Mortalities were removed from the net pen, counted, and scanned for PIT tags. At the time of release, about 500 fish from each group were individually measured and small groups weighed and counted to determine size at release.

Environmental conditions within the estuary and nearshore ocean environment, both biotic and abiotic, will be characterized during each salmonid release-time, primarily by utilizing data from existing Columbia River estuary and plume studies. Existing studies monitor physical conditions including water temperature, salinity, and current at various depths using anchored buoys in the Columbia River estuary and plume (Oregon Graduate Institute Study). The populations of salmonid predators (Pacific hake, Pacific mackerel, jack mackerel) along with the abundance of alternative prey for those predators and for salmonids (northern anchovy, Pacific herring, Pacific sardine), are being evaluated by surface trawling in the Columbia River plume at about 10-day intervals. Our releases were timed to coincide with that sampling effort.

PIT-tag codes from our releases will be recovered from ongoing surveys of Rice Island and East Sand Island conducted by the NMFS in their COE funded efforts to determine losses of PIT-tagged fish from avian predation and the results reported there (Ryan et al. 2001). Our releases will add important information to this study because they will be made at regular intervals with fish of known physiological and disease status. Our release groups will be the only PIT-tag releases in the Columbia River estuary made at regular intervals over the nesting season of piscivorous birds, providing an estimate of vulnerability through time to compare with salmonids migrating from above Bonneville Dam.

Adult returns from serial releases will be evaluated and correlated with the biotic and abiotic conditions smolts encountered in the Columbia River estuary and nearshore ocean environment. Adults will return to Blind Slough beginning in 2004 and will be complete for 2002 releases in 2005. Adult returns will be monitored in the terminal gill net fishery at about a 75% sample rate in the lower Columbia River fishery by ODFW. Adult return rates of PIT-tagged juveniles passing Bonneville Dam or transported and released below Bonneville Dam will also be compared to the CEDC adults with similar time of ocean entry.

Because of the complexity of the marine environment, it is anticipated that multiple years of study will be required to confidently correlate salmonid smolt survival with specific estuary/near-shore ocean environmental conditions.

RESULTS AND DISCUSSION

During 2002, six groups of about 25,000 CWT (with 3,000 PIT-tagged/group) spring chinook salmon smolts were released into Blind Slough at 10-day intervals between 10 April and 30 May (Tables 2-4). Because of poor CWT retention, effective release sizes were smaller, ranging from 20,002 to 21,172 fish/release (Table 4).

Our goal of keeping size constant among release groups was largely achieved, with the mean size per group ranging from 139 to 145 mm for the first five releases and 150 mm for the last release (Fig. 2, Table 4).

Mortality for fish was chronic and higher than normal for all groups while at Willamette Hatchery, in part due to bacterial Cold Water Disease (BCD) caused by *Flexibacter psychrophitus* and *Ichtyobodo*. Mortality while acclimating in Blind Slough (10 days) was less than1.0% for each release group. Most mortalities, both at the hatchery prior to transport to Blind Slough, and while acclimating in the net pens, were fish with crooked spines from previous infection with BCD.

Gill Na^{+}-K^{+} ATPase activity followed a normal development pattern for yearling spring chinook salmon, peaking in late April with a slight decline by the end of May (Fig. 3). Acclimation in the net pens in Blind Slough appeared to stimulate gill ATPase activity in the earliest release groups and slightly retard it for the last two groups. Water temperatures were higher in Blind Slough than at Willamette Hatchery and could have stimulated development, but were perhaps too warm for the last release resulting in slightly lower gill ATPase activity levels.

Over the period of the releases, water temperature in the Columbia River (measured at Beaver Terminal, RKm 87) increased steadily from 8.9 to 14.2°C. Turbidity and discharge varied, with turbidity ranging from 7 to 30 nephelometric turbidity units (NTU) and discharge ranging from 227 to 390 kcfs (Fig. 4). Additional information on physical and biological characteristics of the estuary and nearshore ocean plume environment will be entered into a database during the winter of 2002/2003 to correlate with future SARs. The first adult returns from 2002 releases will be from the Blind Slough terminal gill net fishery in 2004 and will be complete in 2005.

Table 3. Transport dates from Willamette Hatchery, release dates and times into Blind Slough, and Blind Slough water temperature on arrival and at release during 2002.

Transport date	Release date	Release time	Water temperature on arrival (°C)	Water temperature at release (°C)
1 April	10 April	1400	6.1	10.5
10 April	19 April	1400	10.5	8.9
19 April	30 April	1400	8.9	11.1
30 April	10 May	1400	11.1	11.7
10 May	20 May	1350	11.7	13.9
20 May	30 May	1400	13.9	14.4

Table 4. Yearling spring chinook salmon release dates, mean fork length (mm) and number/lb at release, percent mortality in net pens, total numbers released, and numbers with coded-wire tags (CWT) and adipose-fin clips released into Blind Slough in 2002.

Release date	Fork length (s.e.)	Number/lb	Percent mortality	Number of fish released	Number with CWT and ad clip released
10 April	140 (0.9)	14.8	0.38	24,887	21,172
19 April	139 (0.9)	13.6	0.77	23,871	20,082
30 April	139 (0.8)	13.7	0.36	24,164	20,002
10 May	145 (0.9)	13.8	0.21	24,441	20,992
20 May	142 (0.8)	15.7	0.18	23,536	19,646
30 May	150 (0.7)	13.0	0.48	24,403	20,798

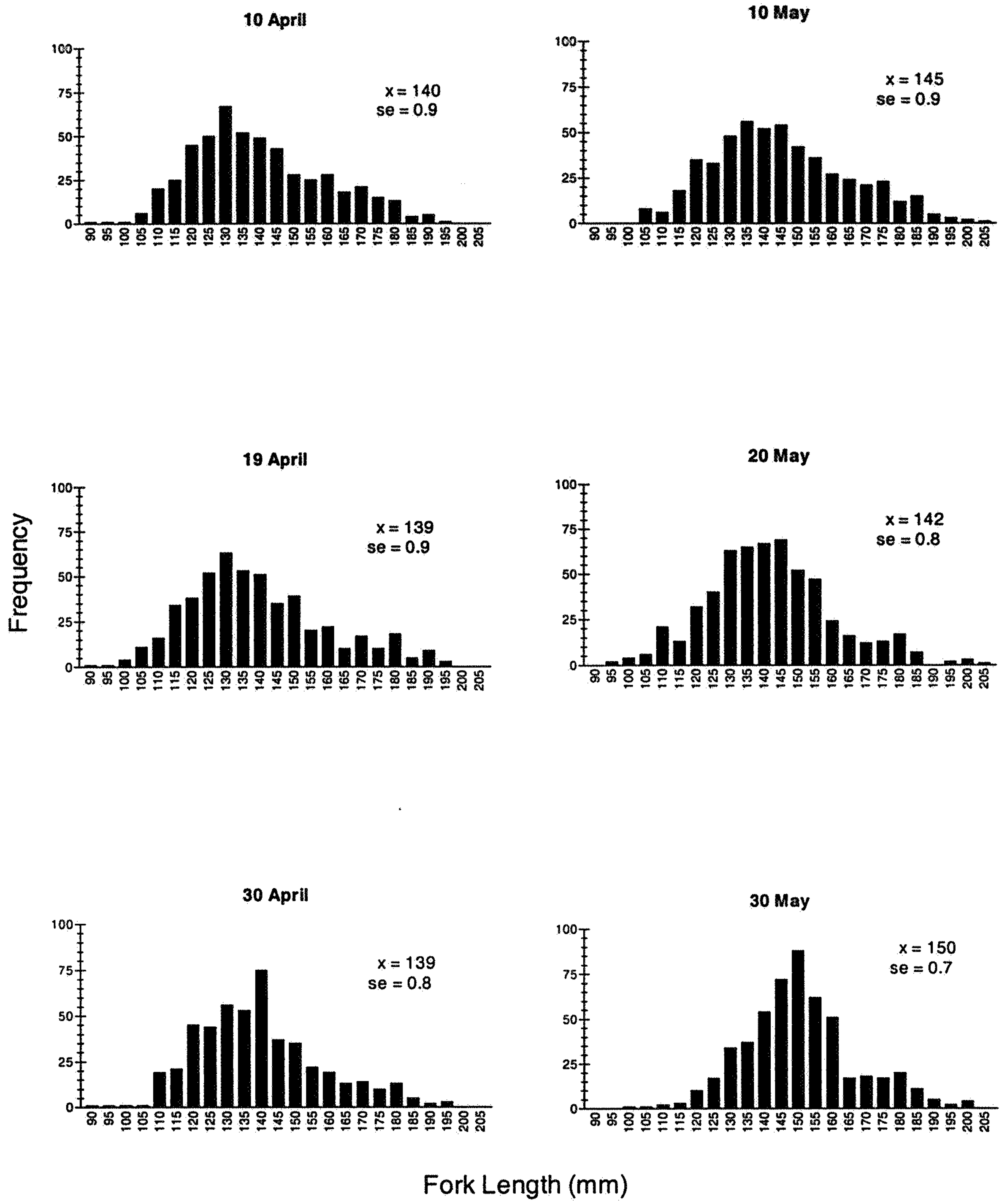

Figure 2. Length frequency (with mean and standard error) of Willamette Hatchery yearling spring chinook salmon at release from net pens into Blind Slough during 2002.

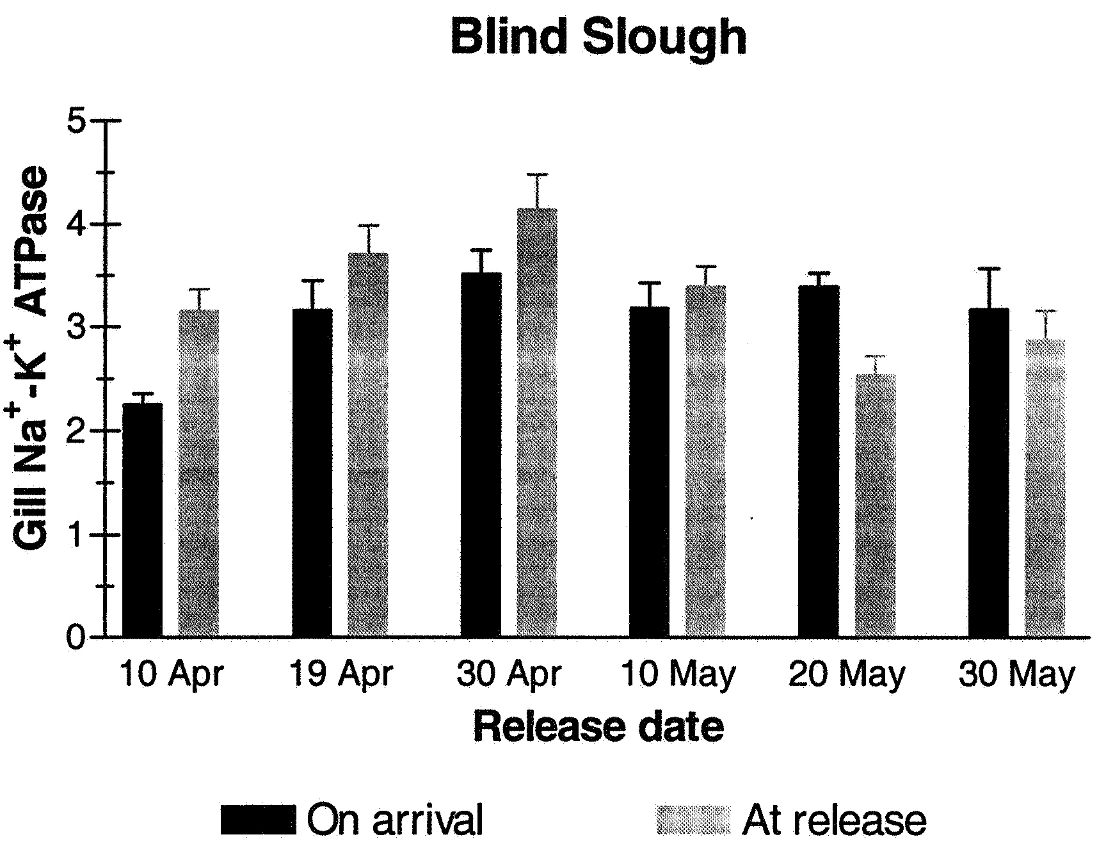

Figure 3. Mean gill Na^+-K^+ ATPase activity in *u*mol Pi · mg $Prot^{-1} \cdot h^{-1}$ (with standard error) for Willamette Hatchery yearling spring chinook salmon on arrival and at release from net pens 10 days later into Blind Slough during 2002.

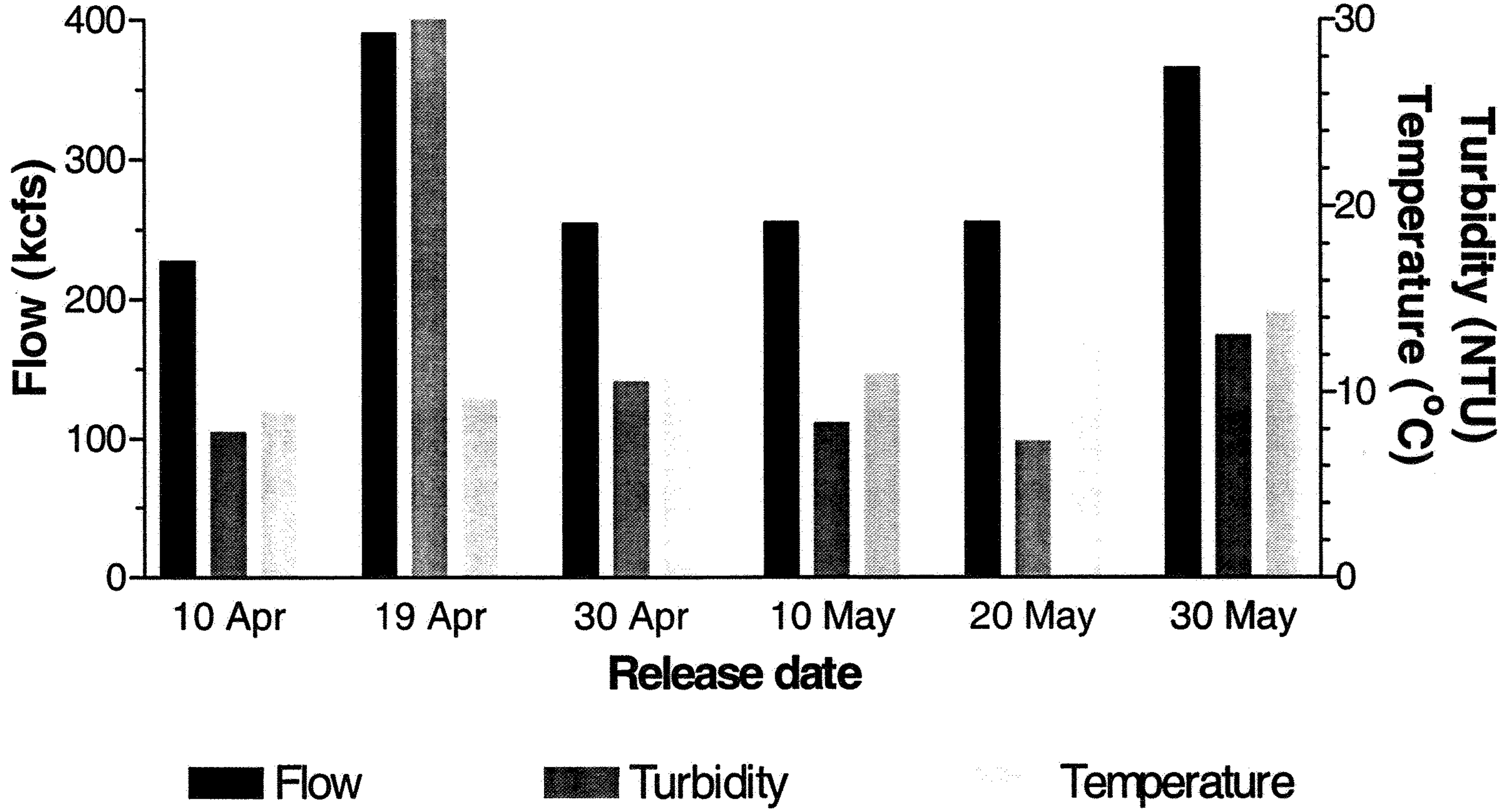

Figure 4. Flow (kcfs), turbidity (NTU), and water temperature (°C) measured at Beaver Terminal on each release date for Willamette Hatchery yearling spring chinook salmon from net pens in Blind Slough during 2002.

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